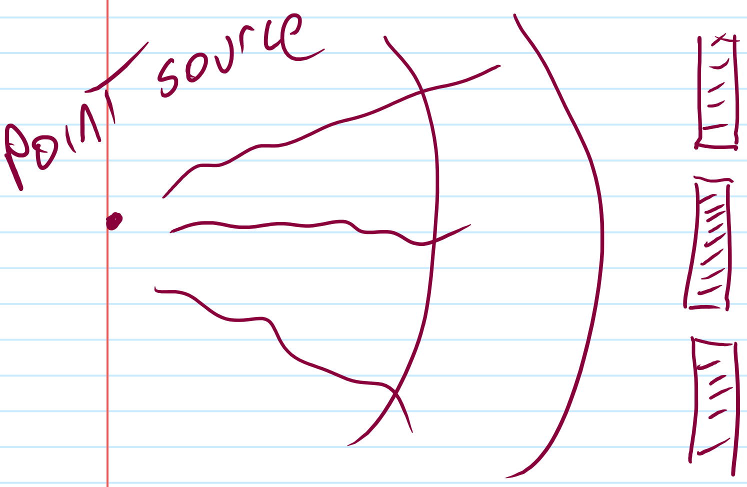
Notes and comments on Michelson interferometer

All interference/diffraction phenomenon result from coherent waves coming together at an endpoint and adding the wave disturbance.

For systems like double slits, Schawlow's ruler, normal sorts of either reflection or transmission diffraction gratings--that is called "Division of Wavefront". A picture shows why.



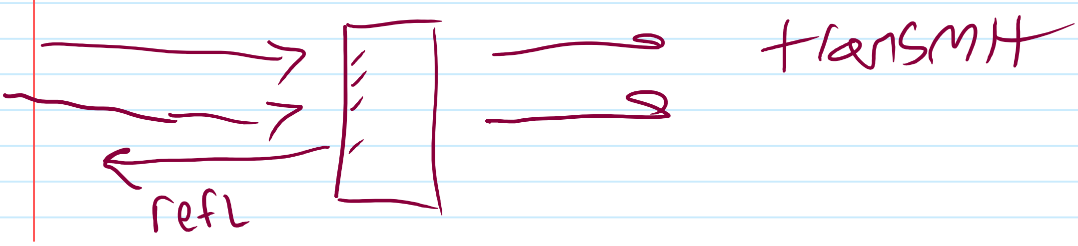
The barrier picks off wave from two distinct regions along a "wavefront".

The wave energy passes through apertures, diffracts (spreads in many directions)---

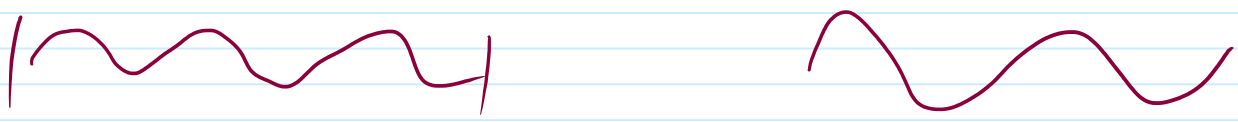
And then may come together at an endpoint.

In order for interference to occur, the two regions sampled must contain waves that are synchronized---or remain coherent, even though they are spatially separated. This is called "spatial coherence".

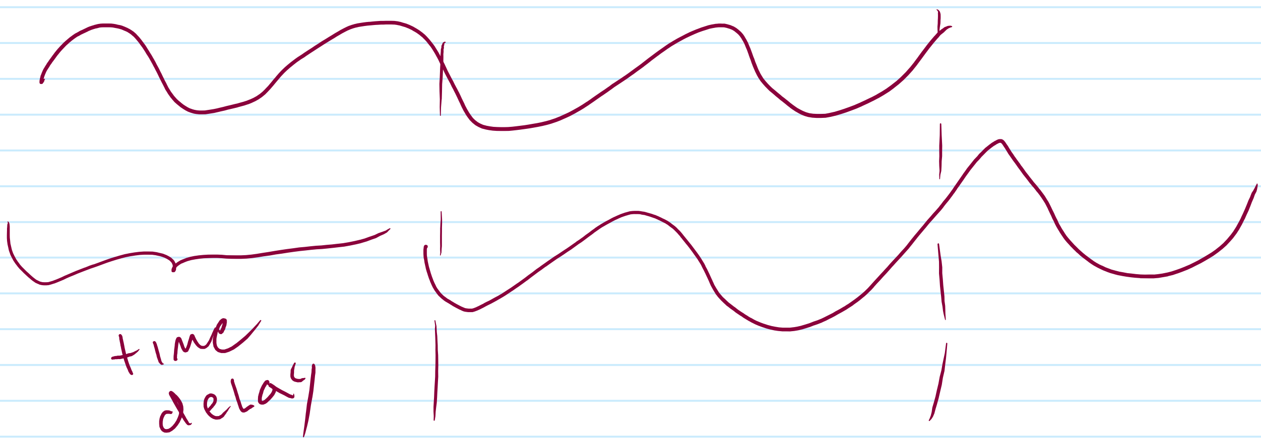
In a Michelson or other partial mirror style interferometers--part of the light passes through a beam splitter. Division of Amplitude--again, a picture displays why.



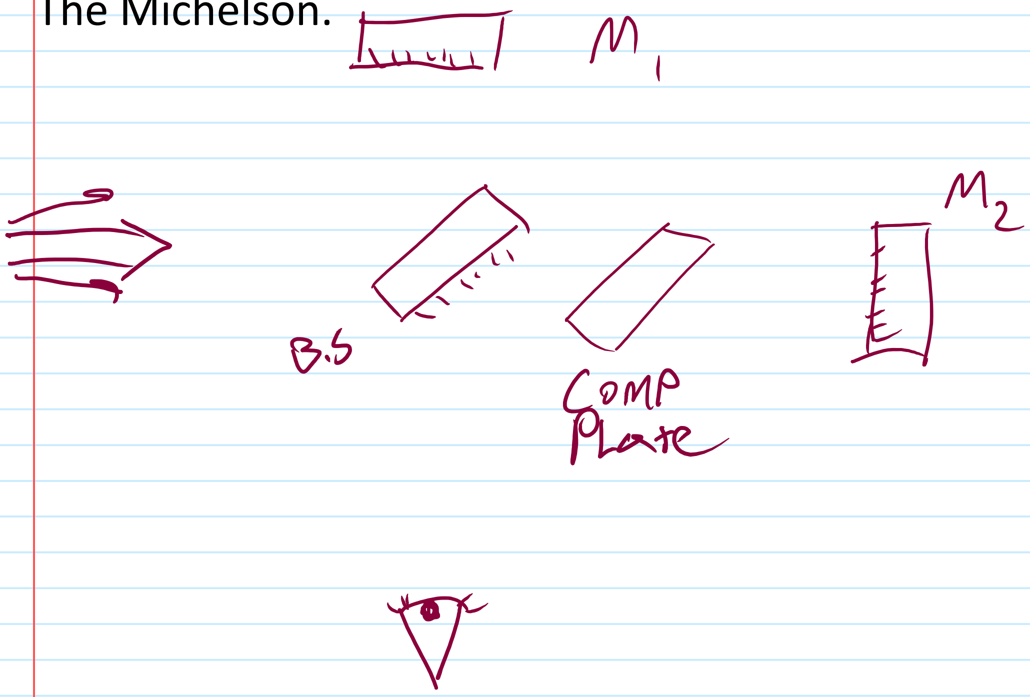
Part of the wave energy (Amplitude) passes through, and part is reflected. The waves can be brought together later at some point by using geometry and mirrors. There are many types of such "Division of Amplitude" devices.   In both cases the light needs to be coherent.   But here if the path difference introduced is too long---the waves will no longer be synchronized.



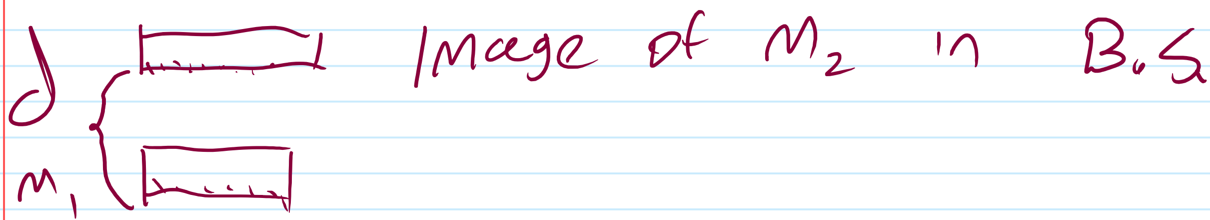
If the path difference is greater than the length of a wave packet, then interference cannot occur. This refers to Coherence length---which really relates to temporal coherence (for how much time do the two waves separate).



The Michelson.



Don’t do this with a laser--but if you stare into the light (not walk--never walk into the light), then you will see partially through the B.S.   to see mirror M1, and you will also see a reflection of mirror M2---which looks to you like it is behind mirror M1.

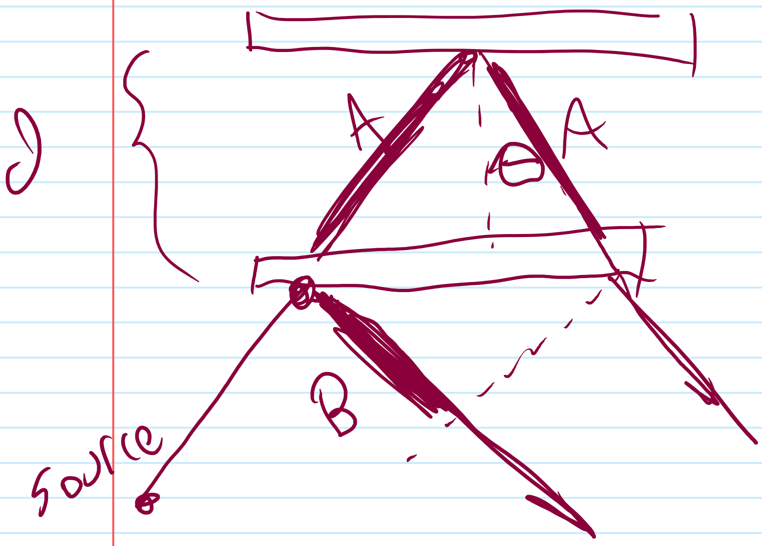


So what you spy with your big eye--will be a single source of light coming from an image of the light source in each mirror. So "part of the same photon" comes from M1, and part from M2   (it is a wave experiment, so I can't really say photon).

The Michelson is in practice very simple. One mirror can move right through (the image) the other!!!!!!!.   By moving the mirror we can set the path difference.

Without deriving from geometry (you can do easily) and noting that light passes through Michelson with some divergence (all light has some divergence). Then we get

$$n\lambda = 2d\cos\theta$$



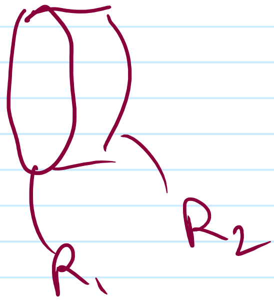
The path difference can be worked out as "2d cos(θ). It is of note that the maximum P.D. is at the center of pattern where the angle is zero. The Zero order fringe is at 90.

Also of technical note only, the beam splitter has a reflection that is internal and one that is external (slow to fast, fast to slow). One of these causes the wave to invert---which is like an extra half cycle of phase difference (half wavelength path difference).

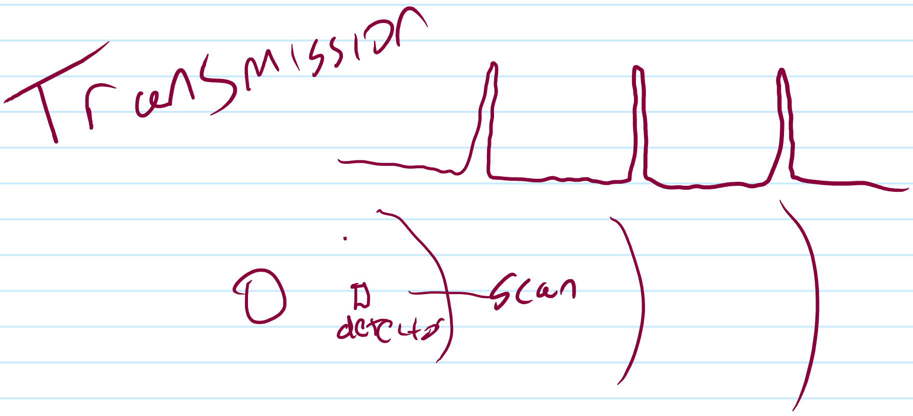
That does not change the fact that every time the mirror moves by λ/2, there is an extra (or missing) full wavelength of PD at the center=one more fringe (or one less). Poof.

Etalons
Fabry Perot

An Etalon--is a simple plate of glass, very parallel, very flat surfaces.

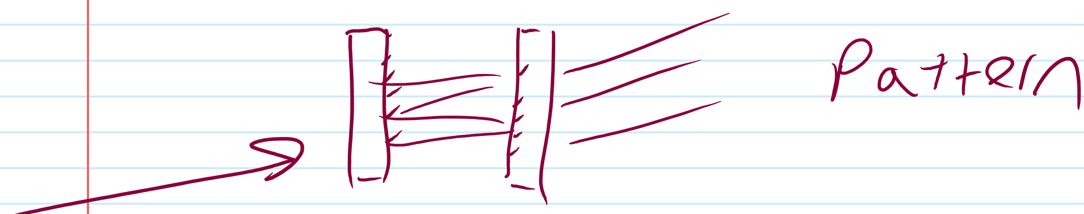


With selected high reflectivity's on each surface, an etalon makes a ring pattern that has a narrow "duty cycle".



The width of a ring compared to the space between rings (free spectral range)---gives spectroscopic information of bandwidth of light spectra.   Higher R leads to better resolution (narrower rings).

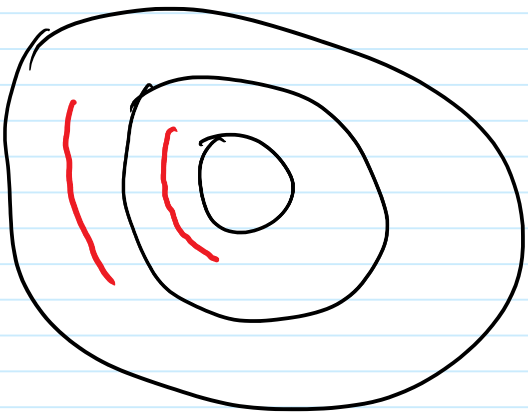
If mirrors are used so that the spacing is variable, then this is called a Fabry-Perot

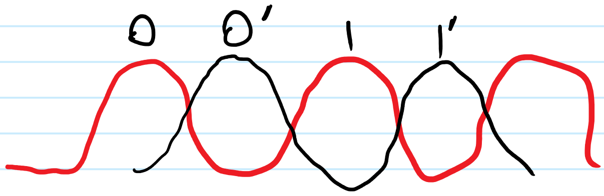


Adding a little curvature and a gain medium in the middle, turns this into a LASER.

In our application we will do two things with the Michelson interferometer.

1) Count fringes passing by near the center of pattern as the mirror is moved. This will determine the wavelength.
2) Observing a pattern that contains two separate (different color and not coherent) ring patterns. The patterns overlap. The colors are so close together that they look the same to us, but when rings from one lay between rings of the other---this is called a "Washout".





We will observe sodium D lines (D1 and D2) which are quite close together.

As the Michelson mirror is adjusted one set of rings appears more rapidly than the other. So instead of fringe 0' being between 0 and 1 (which move), then fringe 0' lies between 1 and 2 on the figure--we get a NEXT WASHOUT.

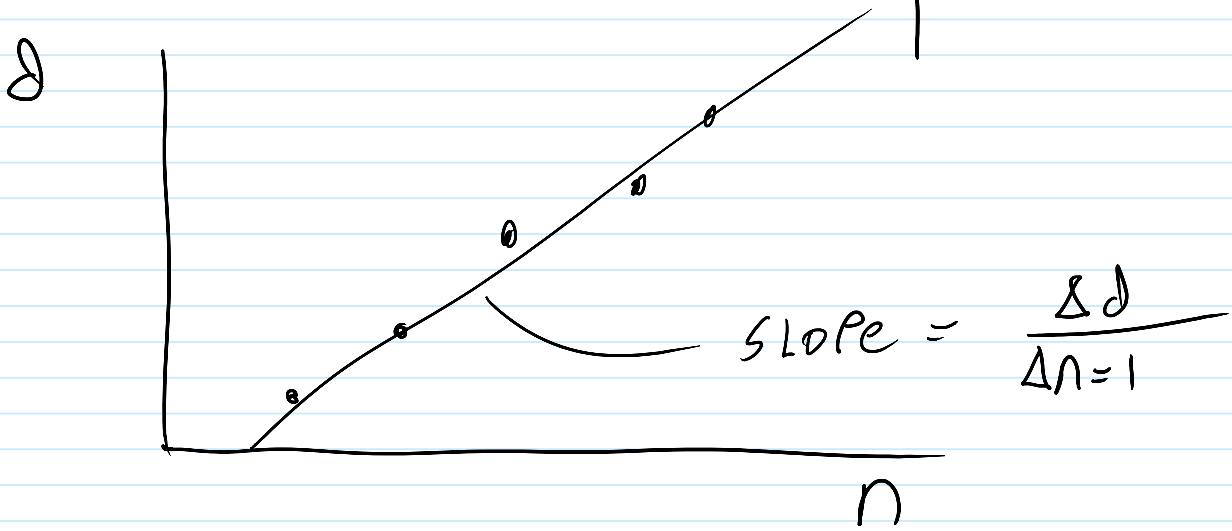
In the Michelson Interferometer task sheet you have been given the result/derivation for relating the spacing between the two spectral lines and space between consecutive washout positions

$$\Delta\lambda = \frac{\lambda_{ave}^2}{2\Delta d}$$

Your data will look like

n	pos
1	δ_1
2	δ_2
3	⋮
⋮	

You will graph the data of
Washout position vs. n



The slope is the spacing between consecutive washouts.
Once you find this, you can find the wavelength separation.

You'll note that this is a simplified form of Fourier spectroscopy (only adding two different frequencies), and this allows you to find the spacing with much higher precision than an individual wavelength can be measured.

You should compare your result for this wavelength spacing, the precision with its uncertainty ----to the raw wavelength measurement you made with the HeNe